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Laser Spectroscopy of the Heaviest Elements at SHIP / GSI

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Laser spectroscopy is a versatile tool to unveil fundamental atomic properties of an element and information on the atomic nucleus. The heaviest elements are of particular interest as their electron shell is strongly influenced by electron-electron correlations and relativistic effects changing the electron configuration and thus, the chemical behavior [1,2]. The elements beyond fermium ($Z > 100$) are only accessible through fusion-evaporation reactions at minute quantities and at high energies, hampering so far their optical spectroscopy. Only recently we were able to identify optical transitions in nobelium ($Z = 102$) in a pioneering experiment employing the RAdiation Detected Resonance Ionization Spectroscopy (RADRIS) technique [3,4]. Nobelium ions are produced in the fusion-evaporation reaction by a ^{48}Ca beam impinging on a lead target. The primary beam is deflected by the velocity filter SHIP and the transmitted recoils are stopped in high-purity argon gas and collected onto a thin tantalum filament. After re-evaporation the neutral atoms were probed by two-step resonance ionization. The so the created photo-ions were then guided to a detector where they were identified by their characteristic α-decay. With this technique a first identification and characterization of a strong $^1S_0 \rightarrow ^1P_1$ ground state transition in nobelium was possible. The resonances for the isotopes $^{252-254}$No were measured as well as the hyperfine splitting in ^{253}No. In combination with atomic calculations, we determined the evolution of the deformation of the nobelium isotopes in the vicinity of the deformed shell closure at neutron number $N = 152$ and extracted the magnetic moment and the spectroscopic quadrupole moment of ^{253}No.

Next steps include the extension of the RADRIS method to more exotic nobelium isotopes and to the next heavier element lawrencium ($Z = 103$) as well as developments for higher resolution spectroscopy. For the latter a dedicated setup is being developed combining the efficient stopping and neutralization from the RADRIS experiment with the high resolution of in-gas-jet spectroscopy [5]. Here, the stopped ions are guided by electric fields to a heated filament, which efficiently neutralizes the nobelium ions, as demonstrated in the RADRIS experiment. The neutral atoms are then extracted through a de Laval nozzle forming a collimated gas jet. Laser spectroscopy in this low density and low temperature regime will enable an improved resolution in laser spectroscopy and furthermore will allow us to address shorter-lived isotopes and isomers as, e.g., the K-isomer in ^{254}No.

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